

## CONTROL OF A PERSONAL TRANSPORTER BASED ON USER POSITION

### CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application is a continuation of U.S. application Ser. No. 15/989,269, filed May 25, 2018, which is a continuation of U.S. application Ser. No. 15/385,077, filed Dec. 20, 2016, which is a continuation of U.S. application Ser. No. 14/619,806, filed Feb. 11, 2015, now U.S. Pat. No. 9,529,365, which is a continuation of U.S. application Ser. No. 14/446,969, filed Jul. 30, 2014, now U.S. Pat. No. 9,188,984, which is a continuation of U.S. application Ser. No. 13/857,737, filed Apr. 5, 2013, now U.S. Pat. No. 8,830,048, which is a continuation of U.S. application Ser. No. 13/585,041, filed Aug. 14, 2012, now abandoned, which is a continuation of U.S. application Ser. No. 12/879,650, filed Sep. 10, 2010, now U.S. Pat. No. 8,248,222, which is a continuation of U.S. application Ser. No. 11/863,640, filed Sep. 28, 2007, now U.S. Pat. No. 7,812,715, which is a divisional of U.S. application Ser. No. 10/939,955, filed Sep. 13, 2004, now U.S. Pat. No. 7,275,607. The present application claims priority from all of the foregoing applications by virtue of the priority chain heretofore recited. All of the foregoing applications are incorporated herein by reference in their entirety.

### TECHNICAL FIELD

[0002] The present invention pertains to control of personal transporters, and more particularly to devices and methods for providing user input with respect to either directional or velocity control of such transporters (having any number of ground-contacting elements) based on the position or orientation of a user.

### BACKGROUND OF THE INVENTION

[0003] Dynamically stabilized transporters refer to personal transporters having a control system that actively maintains the stability of the transporter while the transporter is operating. The control system maintains the stability of the transporter by continuously sensing the orientation of the transporter, determining the corrective action to maintain stability, and commanding the wheel motors to make the corrective action.

[0004] For vehicles that maintain a stable footprint, coupling between steering control, on the one hand, and control of the forward motion of the vehicles is not an issue of concern since, under typical road conditions, stability is maintained by virtue of the wheels being in contact with the ground throughout the course of a turn. In a balancing transporter, however, any torque applied to one or more wheels affects the stability of the transporter. Coupling between steering and balancing control mechanisms is one subject of U.S. Pat. No. 6,789,640, which is incorporated herein by reference. Directional inputs that advantageously provide intuitive and natural integration of human control with the steering requirements of a balancing vehicle are the subject of the present invention.

### SUMMARY OF THE INVENTION

[0005] In accordance with preferred embodiments of the present invention, a controller is provided that may be employed for providing user input of a desired direction of

motion or orientation for a transporter. The controller has an input for receiving specification by a user of a value based on a detected body orientation of the user.

[0006] User-specified input may be conveyed by the user using any of a large variety of input modalities, including: ultrasonic body position sensing; foot force sensing; handlebar lean; active handlebar; mechanical sensing of body position; and linear slide directional input.

[0007] In those embodiments of the invention wherein the transporter is capable of balanced operation on one or more ground-contacting elements, an input is provided for receiving specification from the user of a desired direction of motion, or a desired velocity value based on a detected body orientation of the user. A processor generates a command signal based at least on the user-specified direction and velocity value in conjunction with a pitch command signal that is based on a pitch error in such a manner as to maintain balance of the transporter in the course of achieving the specified direction and velocity. The input of a desired direction may also include a user-specified yaw value, yaw rate value, or fore/aft direction.

[0008] In various other embodiments of the invention, the controller has a summer for differencing an instantaneous yaw value from the user-specified yaw value to generate a yaw error value such that the yaw command signal generated by the processor is based at least in part on the yaw error value. The input for receiving user specification may include a pressure sensor disposed to detect orientation of the user, an ultrasonic sensor disposed to detect orientation of the user, or a force sensor disposed on a platform supporting the user for detecting weight distribution of the user. In yet other embodiments, the input for receiving user specification includes a shaft disposed in a plane transverse to an axis characterizing rotation of the two laterally disposed wheels, the desired direction and velocity specified on the basis of orientation of the shaft.

[0009] In accordance with further embodiments of the invention, the balancing transporter may include a handlebar, and the controller may further have a powered pivot for positioning the handlebar based at least upon one of lateral acceleration and roll angle of the transporter. In particular, the controller may have a position loop for commanding a handlebar position substantially proportional to the difference in the square of the velocity of a first wheel and the square of the velocity of a second wheel.

[0010] In accordance with yet other embodiments of the invention, an apparatus is provided for prompting a rider to be positioned on a vehicle in such a manner as to reduce lateral instability due to lateral acceleration of the vehicle. The apparatus has an input for receiving specification by the rider of a desired direction of travel and an indicating means for reflecting to the rider a desired instantaneous body orientation based at least on current lateral acceleration of the vehicle. The indicating means may include a handlebar pivotable with respect to the vehicle, the handlebar driven in response to vehicle turning.

### BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The foregoing features of the invention will be more readily understood by reference to the following detailed description, taken with reference to the accompanying drawings, in which: